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ESTIMATION OF SURFACE RUNOFF IN TIMMAPUR WATERSHED USING SCS-CN METHOD

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ABSTRACT

The development of watershed aims at productive utilization of all the available natural resources in the entire area extending from ridge line to stream outlet. The per capita availability of land for cultivation has been decreasing over the years. Therefore, water and the related land resources must be developed, utilized and managed in an integrated and comprehensive manner. Remote sensing and GIS techniques are being increasingly used for planning, management and development of natural resources. The study area, Timmapur watershed geographically lies between 16°15' and 16°30' N latitude and 77° 15' and 77° 30' E longitude with an area of 101.34 Sq. km. The thematic layers such as land use/land cover and soil maps were derived from remotely sensed data and overlayed through Arc GIS software to assign the curve number. The daily rainfall data of nearby rain gauge station (2001-2011) was used to estimate the daily runoff from the watershed using Soil Conservation Service - Curve Number (SCS-CN) method. The runoff estimated from the SCS-CN model was then used to know the variation of runoff potential with different land use/land cover and with different soil conditions.

KEYWORDS: GIS, Rainfall-Runoff, Remote Sensing, SCS-CN, Surface Runoff, Watershed

INTRODUCTION

A watershed is the area covering all the land contributes runoff water to a common point. It is a natural physiographic or ecological unit composed of interrelated parts and function. Each watershed has definite characteristics such as size, shape, slope, drainage, vegetation, geology, soil, geomorphology, climate and land use. Watershed management implies the proper use of all land and water resources of a watershed for optimum production with minimum hazard to natural resources. Runoff is one of the important hydrologic variables used in the water resources applications and management planning. Estimation of surface runoff is essential for the assessment of water yield potential of the watershed, planning of water conservation measures, recharging the ground water zones and reducing the sedimentation and flooding hazards downstream. Also, it is an important and essential prerequisite of Integrated Watershed Management (Subramanya,2008). Remote Sensing and GIS techniques are being increasingly used for planning, development and management of natural resources. GIS in particular help in integrating various data sets and perform spatial analysis for decision making. GIS and remote sensing are presently being used for solving environmental problems like degradation of land by water logging, soil erosion, deforestation, changes in ecological parameters and many more. Jasrotia*et al.,* used a

mathematical model to estimate rainfall, runoff in conjunction with remote sensing data and GIS using SCS CN method and runoff potential map.

Ashish and Dabral (2004) estimated the runoff from SCS curve number model modified for Indian condition by conventional data base and GIS for Dikrong river basin. AmuthaandPorchelvan (2009) showed that estimation of runoff by SCS-CN method integrated with GIS can be used in watershed management effectively. Somashekar*et al.*,estimated surface runoff of Hesaraghatta watershed. The analysis was carried using IRSID LISS III satellite images in the form of FCC using SCS curve number method and found that the runoff estimated by SCS method shown reasonable good result.

MATERIAL AND METHODOLOGY

Study Area

The study area, Timmapur watershed is located in Raichur district and geographically lies between 16°15’ and 16°30’ N latitude and 77° 15’ and 77° 30’ E longitude with an area of 101.34 Sq. kmas delineated from Survey of India (SOI) toposheet. Maximum length and average width of watershed are 18.08 km and 5.60 km respectively. Figure 1 shows the location map of the study area.The highest relief in the watershed is found to be 326 m and the lowest relief is 255 m above the mean sea level.The overall relief of the watershed is found to be 70 m (Figure 2).The soils in the watershed are loamy skeletal, loamy and fine (Figure 3).

Data Used

The Survey of India topographic maps no 56H/7 and 56H/3 were used for the demarcation of the watershed boundary on 1:50000 scale. The rainfall data of Timmapur watershed for the year 2012 was collected from Main Agricultural Research Station, Raichur. The land use and land cover map (Figure 4) was prepared using hybrid classifier for IRS 1CLISS III satellite imagery during the year 2012 with a resolution of 23.5m. The Drainage map (Figure 5) is created for the study area using ArcGIS 10 software. The soilinformation was collected from the soil map prepared by Karnataka State Remote Sensing Application Centre (KSRSAC).

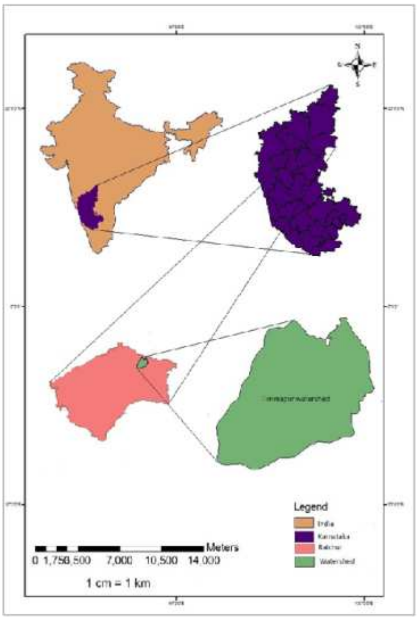

Figure 1: Location Map of the Study Area

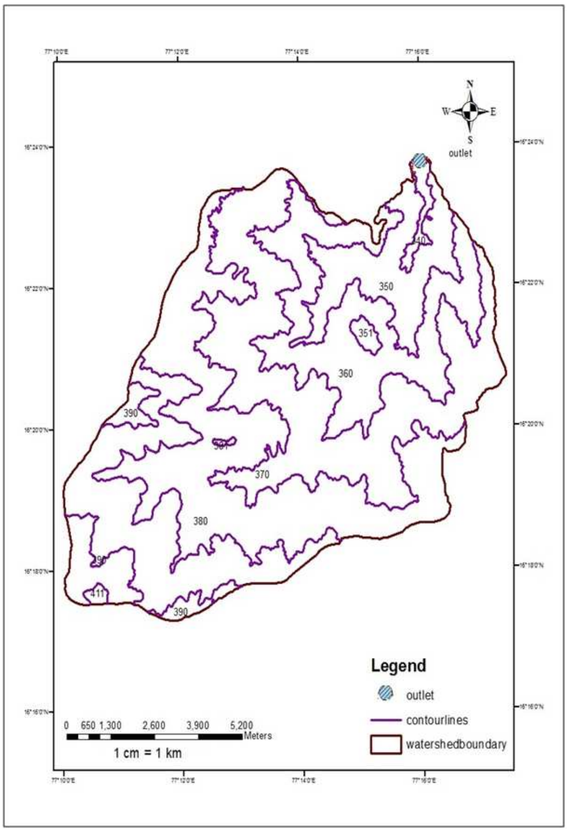

Figure 2: Contour Map of Timmapur Watershed

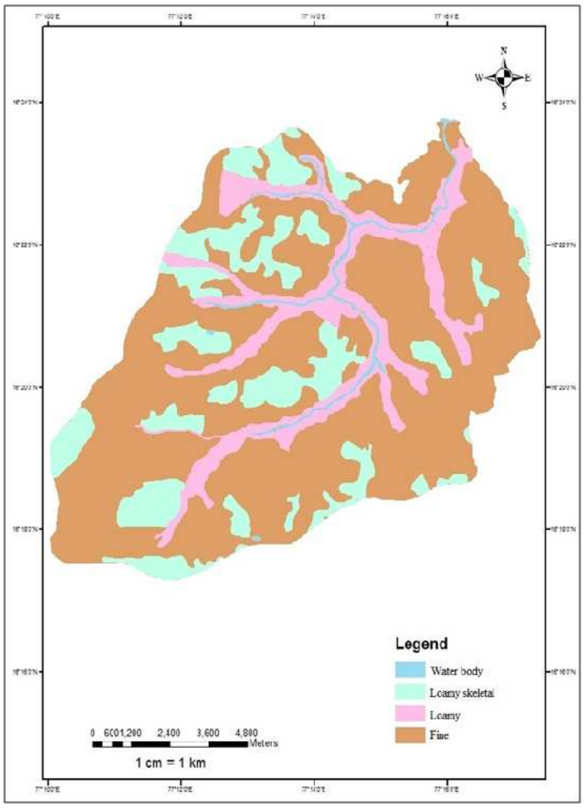

Figure 3: Soil Map of Timmapur Watershed

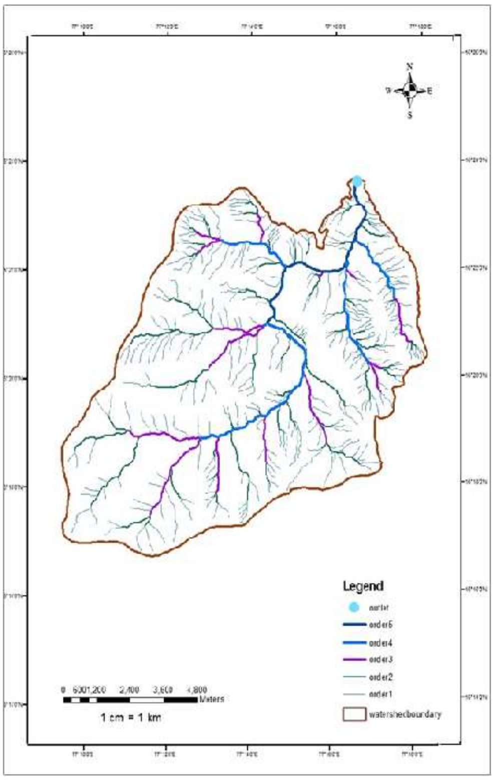

Figure 4: Drainage Map of Timmapur Watershed

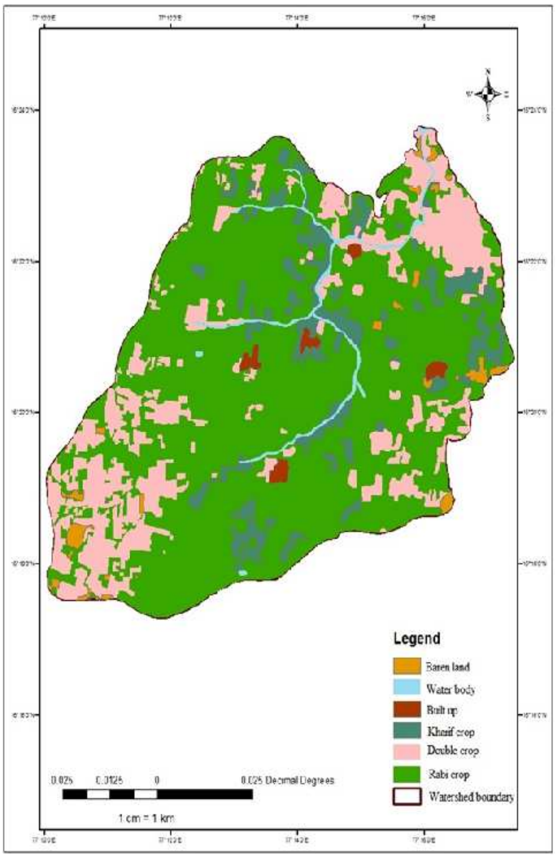

Figure 5: LU/LC Map of Timmapur Watershed

Land Cover/Land Use Classification

In order to study land cover/ land use pattern for the study area we have used hybridclassifier. Hybrid Classification includes the advantages of both supervised as well asunsupervised classification. For unsupervised classification, K-meansclusteringalgorithm is used followed by supervised classification.

SCS Curve Number Model

SCS rainfall runoff model, developed by United States Department of Agriculture(USDA) provides an empirical relationship estimating initial abstraction and runoff as afunction of soil type and landuse. To estimate the curve number, depth of rainfall the land use/land cover and soil map were integrated.

Runoff Volume

Surface runoff is mainly controlled by the amount of rainfall, initial abstraction and moisture retention of the soil. The SCS curve number method is based on the water balance equation and two fundamental hypotheses which are stated as, ratio of the actual direct runoff to the potential runoff is equal to the ratio of the actual infiltration to the potential infiltration, and the amount of initial abstraction is some fraction of the potential infiltration.The water balance equation is expressed by

$$P = I_a + F + Q \qquad \text{Eq. 1}$$

$$\frac{Q}{(P - \mathrm{I_a})} = \frac{F}{S} \qquad \text{Eq. 2}$$

Combination of Equations (1) and (2) leads to the most popular form of the SCS-CN method:

$$Q = \frac{(P - \mathrm{I_a})^2}{(P - \mathrm{I_a}) + \mathrm{S}} \qquad P \geq \mathrm{I_a} \qquad \text{Eq. 3}$$

The SCS-CN parameter S for the present study is calculated at the watershed level by using the formula:

$$S = 254\left(\frac{100}{CN} - 1\right) \qquad \text{Eq. 4}$$

The median CN value represents the AMC II condition and depending on the 5day precipitation amount, it isconverted to AMC I or AMC III using National Engineering Handbook Section 4 (NEH-4) tables (SCS 1972). Thisapproach is applicable for both gauged and ungauged catchments, and CN values derived from NEH-4 tables dependson watershed characteristics such as soil type, LU/LC, slope, hydrological condition and antecedent soil moisturecondition (AMC).

The SCS-CN is a function of the ability of soils to allow infiltration of water with respect to LU/LC and AMC.According to U.S. SCS, soils are divided into four hydrological soil groups, namely, A, B, C and D, with respect to therate of runoff potential and final infiltration rate.

SCS developed soil classification system that consists of fourgroups, which are identified as A, B, C, and D according totheir minimum infiltration rate. Table 1 shows the hydrological soil group classification. CN values weredetermined from hydrological soil group and antecedentmoisture conditions of the watershed. The Curve Numbervalues for AMC-I and AMC-II were obtained from AMC-II(Chow et al. 1988) by the method of conservation. Runoffcurve numbers (AMC II) for hydrologic soil cover complex are shown in Table 2.

Table 1: Classification of Antecedent Moisture Conditions (AMC)

AMC Class	Description of Soil Condition	Total Five Day Antecedent Rainfall (Mm)	
		Dormant Season	Growing Season
I	Soils are dry but not to the wilting point; satisfactoryCultivation has taken place.	< 12.7 mm	< 35.56 mm
II	Average conditions.	12.7-27.94 mm	35.56-53.34 mm
III	Heavy rainfall or light rainfall and low temperature shave occurred within last 5 days; Saturated soils.	> 27.94 mm	53.34 mm

Table 2: Hydrological Soil Group Classification (Mc. Cuen, 1982)

SoilGroup	Description	Minimum Infiltrationrate (mm/hr)
A	Soils in this group have a low runoff potential (high-infiltration rates) even when thoroughly wetted. They consist of deep, well to excessively welldrained sands or gravels. These soils have a high rate of water transmission.	7.62 - 11.43
B	Soils in this group have moderate infiltration rates when thoroughly wetted and consists chiefly of moderately deep to deep, well-drained to moderately well-drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.	3.81 - 7.62
C	Soils have slow infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes the downward movement of water, or soils with moderately fine-to fine texture. These soils have a slow rate of water transmission.	1.27 - 3.81
D	Soils have a high runoff potential (very slow infiltration rates) when thoroughly wetted. These soils consist chiefly of clay soils with high swelling potential, soils with a permanent high-water table, soils with a clay layer near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.	0 - 1.27

RESULTS AND DISCUSSIONS

The study area constitutes different land use/ land cover about 67.8% of the area is occupied by *Rabi* crop land, 8.05% of the area occupied by *Kharif* crop land, 20.14% of area by double crop land, 1.47% of area by Barren land and remaining 2.54% of the areais occupied by others such as, water body, settlement. In general, among the different landcover types the crop land plays the major role for the directsurface runoff.The SCS-CN method was used both Curve Number and weighted CN was calculated based on the overlaid LULC map and presented in Table 3. Annual rainfall for the year 2012 was calculated which is 350.3 mm and runoff depth was found to be 18.16 mm.

Table 3: Spatial Distribution of Land Use Features in Timmapur Watershed and Corresponding CN Values

Land Use/ Land Cover	Soil Group	Area(Km^2)	Area (%)	Curve Number	Weighted Curve Number(Cn_w) For Amc
Rabi Crop	C	68.71	67.80	88	AMC I=76.35 AMC II=88.04 AMC III=94.52
Double crop land	C	20.41	20.14	88	
Kharif Crop	C	8.15	8.05	88	
Built up	C	1.02	1.00	90	
Water body	C	1.56	1.54	100	
Barren land	C	1.49	1.47	77	
Total		**101.34**	**100**	**CN_W 88.04**	

CONCLUSIONS

The estimation of runoff using GIS based SCS curve numbermethod can be used in watershed management effectively. Allthe factors in SCS model are geographic in character. Due tothe geographic nature of these factors, SCS runoff model canbe easily molded into GIS. The study demonstrates theimportance of remotely sensed data in conjunction with GIS toderive the model parameter to estimate surface runoff from theungauged watershed. Results obtained clearly shows thevariation in runoff potential with different land use/land coverand with different soil conditions. Based on the digitaldatabase creation, conservation techniques such as percolationpond, check dam etc., can be recommended for bettermanagement of land and water resources for sustainabledevelopment of the watershed.

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